Preliminary Assessment of the Effect of Ambient Temperature on the Performance of Air-Cooled Geothermal Power Plants at a Typical Site in South Australia

Langman, A.S.[1], Battye, D.[1], Nathan, G.J.[1], Ashman, P.J.[1], Dally, B.B.[1] and Oakeshott, C.[2]
[1] *Fluid Mechanics, Energy and Combustion Group, The University of Adelaide*
[2] *Electricity Supply Industry Planning Council, SA.*

ABSTRACT

The paper aims to undertake a relative comparison of the performance and mechanical systems required to extract power from a geothermal site under typical conditions that are expected to apply in South Australia. A distinguishing feature of this assessment is the combination of high day-time ambient temperatures, the use of an air-cooled system due to the assumed requirement to reinject all of the geothermal liquid, and the lack of any alternative water source from which to facilitate a cooling tower. The investigation considers a site at which the geoliquid reaches the surface at a temperature of 210 °C, and the effect of variations in ambient temperature from 15 - 45 °C. A single stage flash cycle, an Organic Rankine Cycle (ORC) and Kalina cycle are chosen for this preliminary assessment, since the trends are likely to apply for more advanced cycles, although with lower absolute performance.

The calculations are performed using standard analytical approaches. It is assumed that the geo-liquid is maintained at sufficient pressure to be in a liquid state throughout the pipes and aquifer, and that there is no leakage. Hence, a leakage of 5 - 10 %, which is often assumed for such systems, would increase parasitic pumping requirements by the square of the additional flow-rate. It is also assumed that no non-condensable gases (NCG's) are present, which represents a best-case scenario. The isentropic efficiency of the turbine was calculated based on the vapour quality. The ORC is calculated assuming Pentane as the working fluid, and only basic optimisation is performed for the Kalina cycle, so the calculations will somewhat under-predict what is possible for this cycle.

The low thermal efficiency of geothermal systems makes the condenser a highly capital intensive item. Hence a detailed model of an air-cooled condenser was developed. The ambient air has been assumed to be completely dry (0 % humidity) and no fouling factors have been included for the condenser. The design procedure was based on established procedures. The Overall Heat Transfer Coefficient (OHTC), fan power and the Log-Mean Temperature Difference (LMTD) between the cooling air and the condensate are not independent variables. A sensitivity study was used to determine that a LMTD of around 15 to 20 °C degrees is the most suitable. At smaller LMTD's the condenser size required increases dramatically. Similarly, the cooling air temperature rise that is most suitable is 19-25 °C. The combination of these two variables gives a moderate approach velocity of 4-5 m/s, high enough for a good OHTC and low enough so that the pressure drop (and hence fan power) are moderate (less than 10 % of the net power generated before re-injection). The resulting size of air coolers is large, with a typical size calculated to be 10 m tall x 8.48 m long x 0.182 m thick per MW for the pentane ORC.

Figure 1 presents the effect on subnet power (before pumping losses), of variations in ambient temperature. It is evident that increasing the ambient temperature from 15 to 45 °C is calculated to

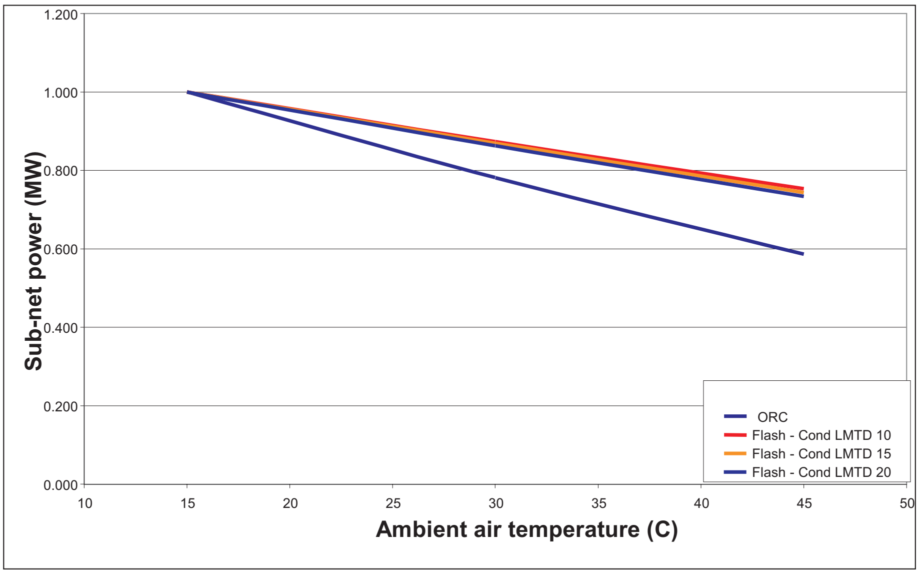

Figure 1. The relative sub-net power production of the ORC and flash systems as a function of the ambient air temperature.

cause a drop in output of subnet power of 30% for the flash cycle, and 40% for the pentane ORC. This is particularly significant because it causes a significant mis-match between the output power and the demand cycle, with peak demand typically being well correlated with peak ambient temperature.

The investigation also assessed the impact of pumping power as a parasitic loss. Figure 2 compares the influence on sub-net power of the reinjection pressure needed to over-come net pumping losses (i.e. after the thermo-syphon has been accounted for) through pipes and reservoir. These calculations all assume that the geothermal liquid reaches the surface at approximately ambient pressure and that the ambient temperature is 15 °C. It is evident that there are slight differences between the three cycles, and that losses become significant. For example, pumping losses of 10 MPa results in a reduction in net power of about 25 % for all cycles. The paper will also compare

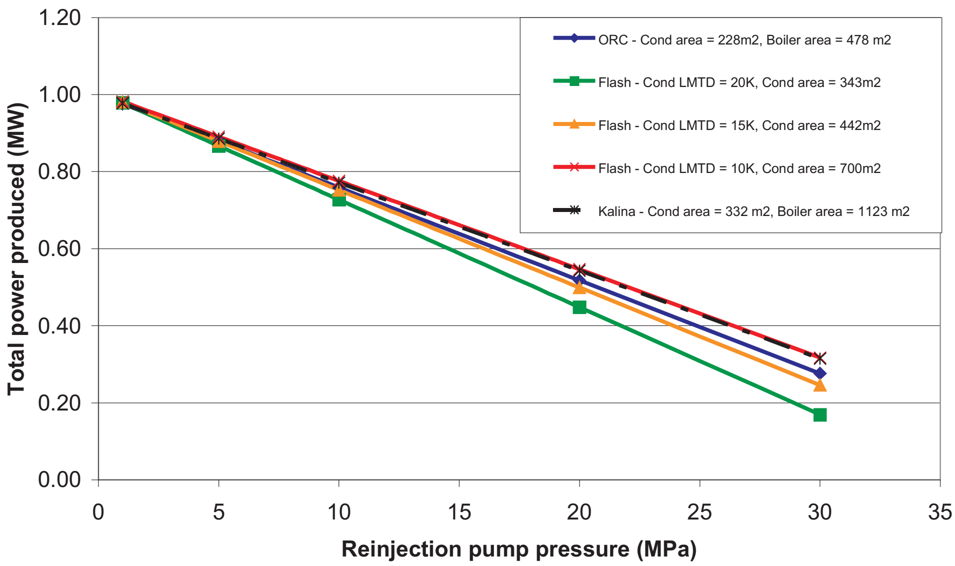

Figure 2. The effect of net re-injection pump pressure required to overcome parasitic pumping losses on all three cycles, based on an ambient temperature of 15 °C.

the sizes of key components for the three cycles, discuss key differences between them, and comment on the role of NCG's.